# Directional Difference of Satellite Land Surface Temperature

Yunyue Yu

NOAA/NESDIS/STAR

# Outline

- Research Motivation
- Concept of the Directional Effect
- Directional Effect Observed in Polar-orbiting Satellite Data
- Directional Effect Observed in Geostationary Satellite Data
- Possible Solutions?

# Research Motivation

Is Directional LST Difference Significant ?

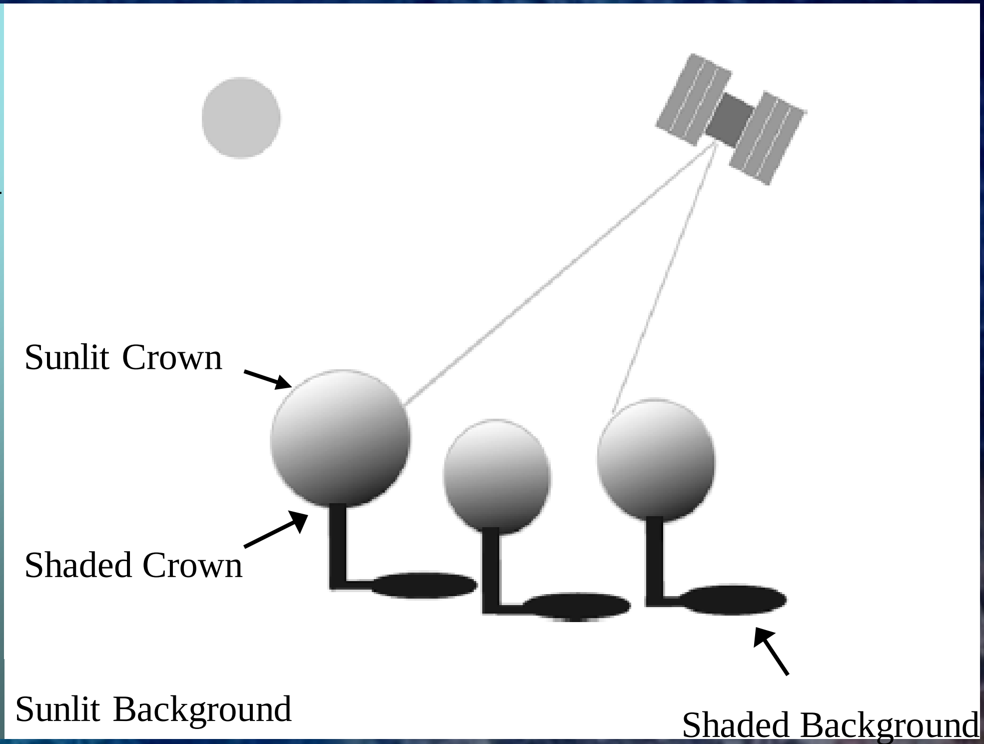
- Affect to LST validation process
- Affect to produce climate data record
- Affect to LST applications, e.g. data assimilation for forecast model

# Concept of the Directional Effect

## One of directional effect described by Modified Geometric Projection Model

$$\langle T(\theta,\phi)\rangle = \left[\frac{1}{\langle \varepsilon(\theta,\phi)\rangle}\sum_{k=1}^{N}\varepsilon_k T_k^4 X_k(\theta,\phi)\right]^{1/4}$$

$$\langle \varepsilon(\theta,\phi)\rangle = \sum_{k=1}^{N}\varepsilon_k X_k(\theta,\phi)$$




$k=N$ endmembers

- $X$: fraction of the cover probability
- $\varepsilon$: emissivity of the endmember
- $T$: temperature of the endmember

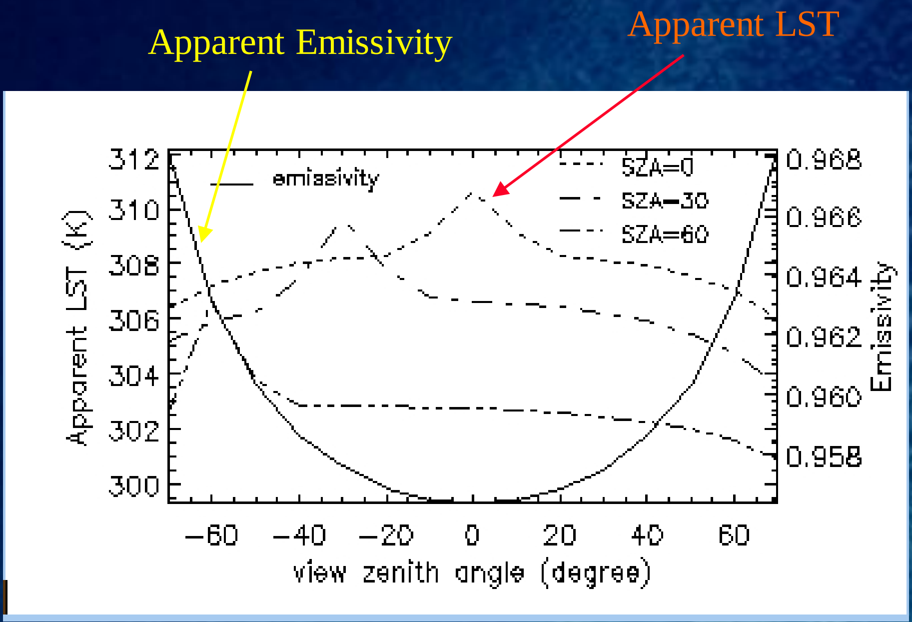
Four endmembers:

Sunlit Crown, Shaded Crown

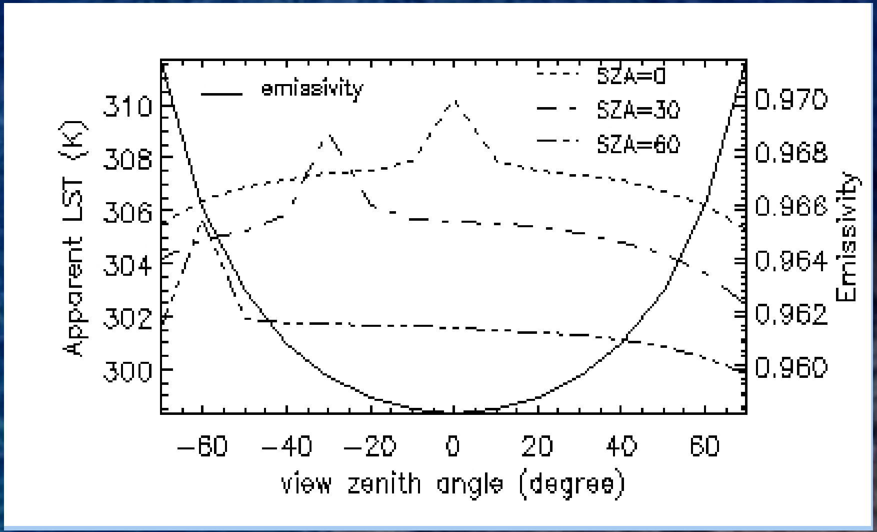
Sunlit background, Shaded Background

# Concept of the Directional Effect
## MGP Model Run Example

Examples of the surface temperature distributions and the mean emissivity distributions (solid line) along with the satellite view zenith angle. The temperature and emissivity distributions are calculated from the MGP model temperature settings, for solar zenith angle at 0, 30 and 60 degrees, respectively; the LAI value is 1.

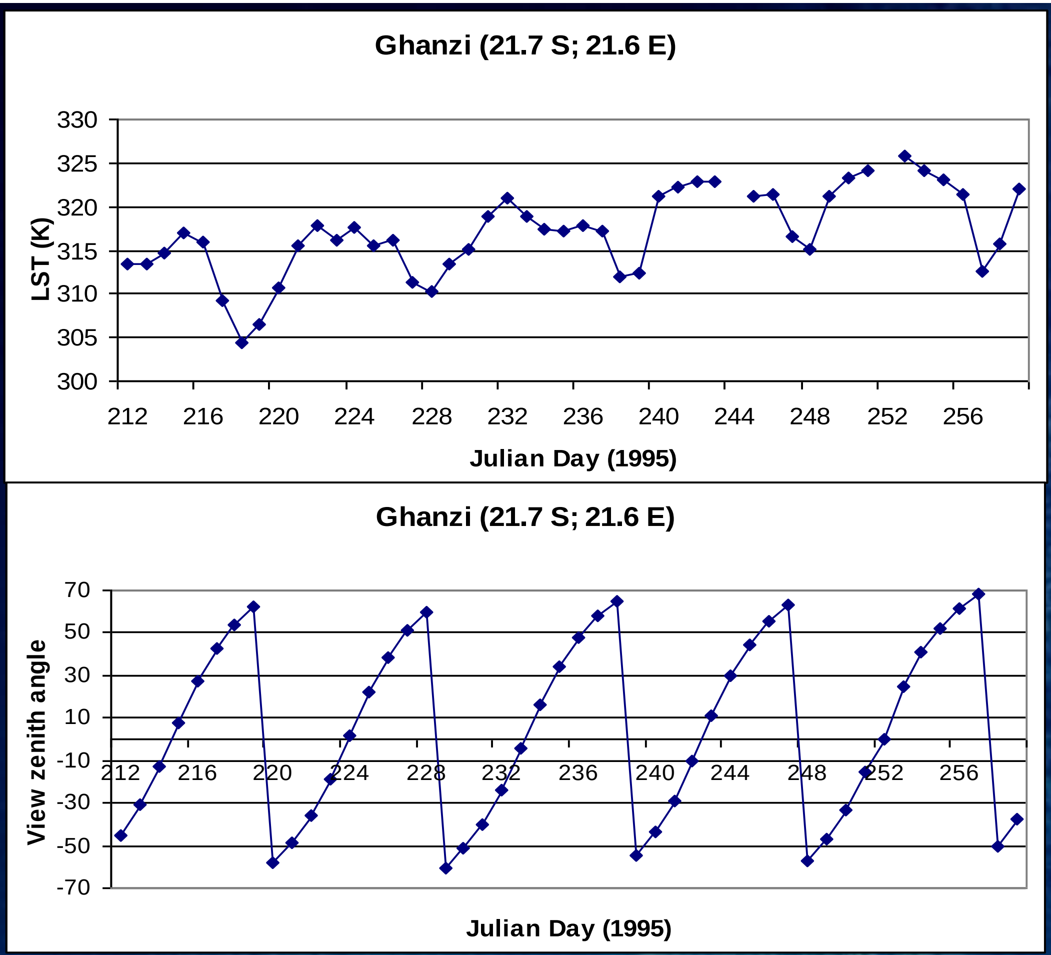



The vegetation coverage is **30%.**




The vegetation coverage is **60%.**

# Directional Effect Observed in AVHRR Data



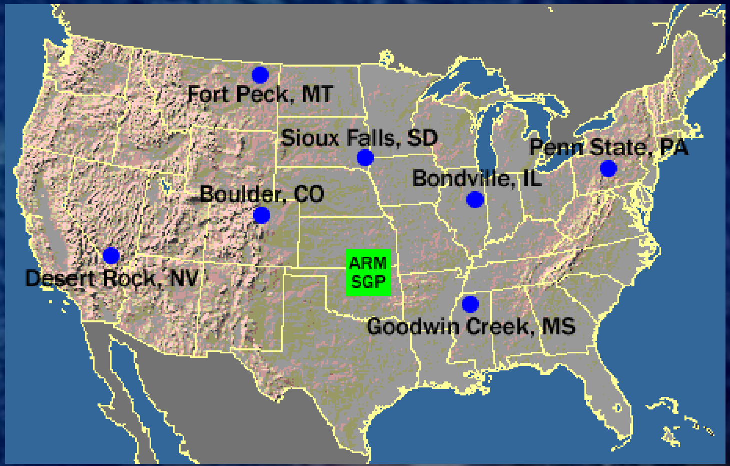

<u>Daily daytime AVHRR</u> a) Land surface temperature and
b) View zenith angle.
*[Pinheiro et al., Remote Sensing of Environment, 103 (2006)]*


Daytime AVHRR, LST observations, at Ghanzi, Botswana

Demonstrated LST variability is a combination of:
a) residual atmospheric effects
b) real aggregate temperature differences
c) emissivity angular variability

# Directional Effect Observed in Geostationary Satellite Data

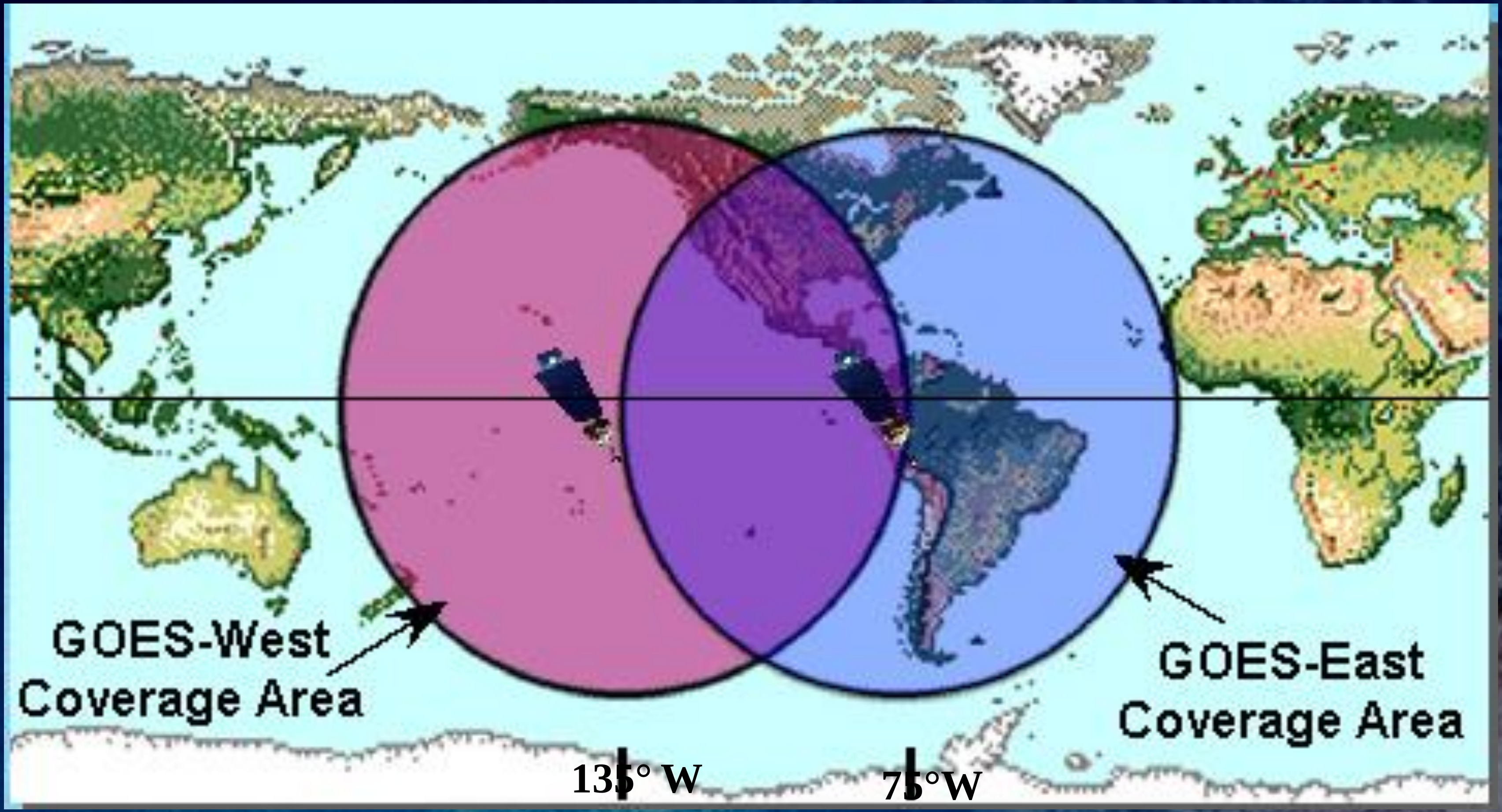
GOES-8 and GOES-10 Imager data were aqpplied in validating LST algorithm using ground data from SURFace RADiation (SURFRAD) budget network stations




| No. | Site Location | Lat/Lon | Surface Type* |
|---|---|---|---|
| 1 | Pennsylvania State University, PA | 40.72/77.93 | Mixed Forest |
| 2 | Bondeville, IL | 40.05/88.37 | Crop Land |
| 3 | Goodwin Creek, MS | 34.25/89.87 | Evergreen Needle Leaf Forest |
| 4 | Fort Peck, MT | 48.31/105.10 | Grass Land |
| 5 | Boulder, CO | 40.13/105.24 | Crop Land |
| 6 | Desert Rock, NV | 36.63/116.02 | Open Shrub Land |


Duration of Data: Jan 1 – Dec 31, 2001

# Two-directions from GOES Satellites

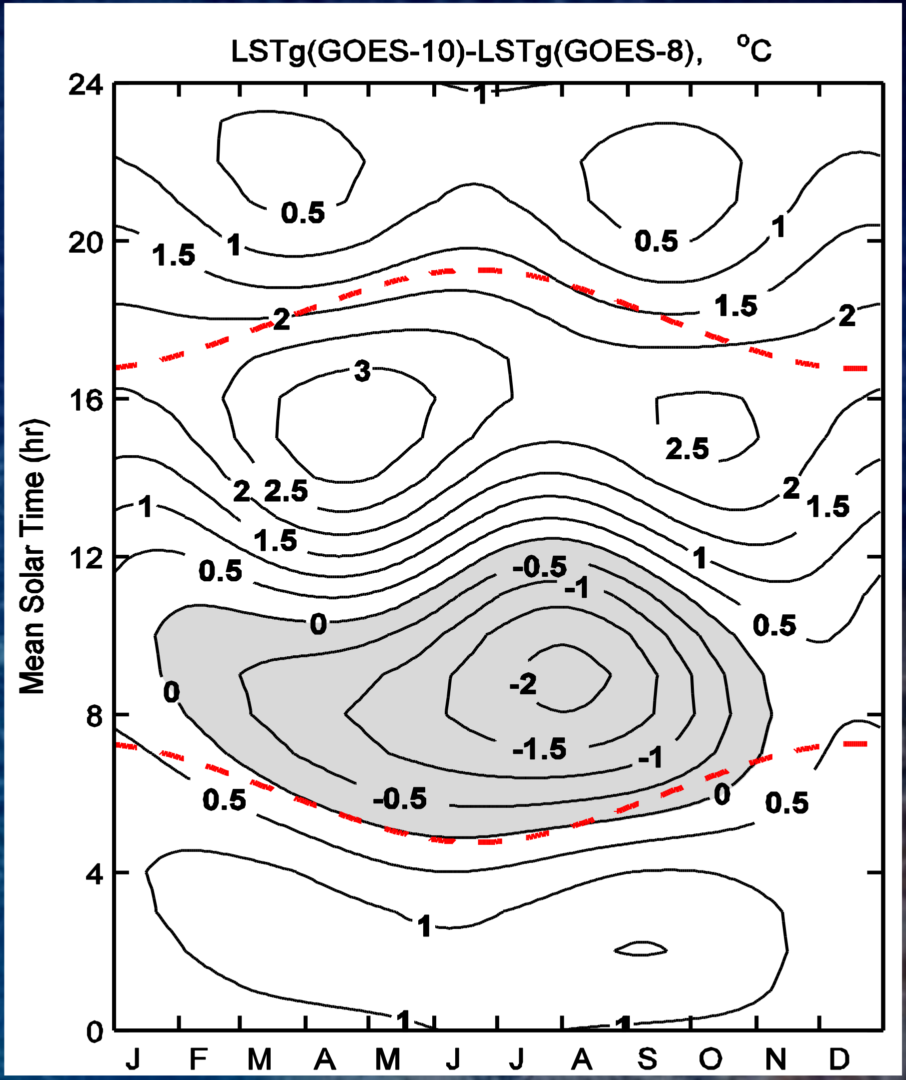


# LST Directional Effect in GOES-8 and -10 Imager

Difference of LSTs observed by GOES-10 and GOES-8 imager at the same location of SURFRAD station Desert Rock, NV, 36.63ºN, 116.02ºW. The simultaneous observation pairs are about 2096.

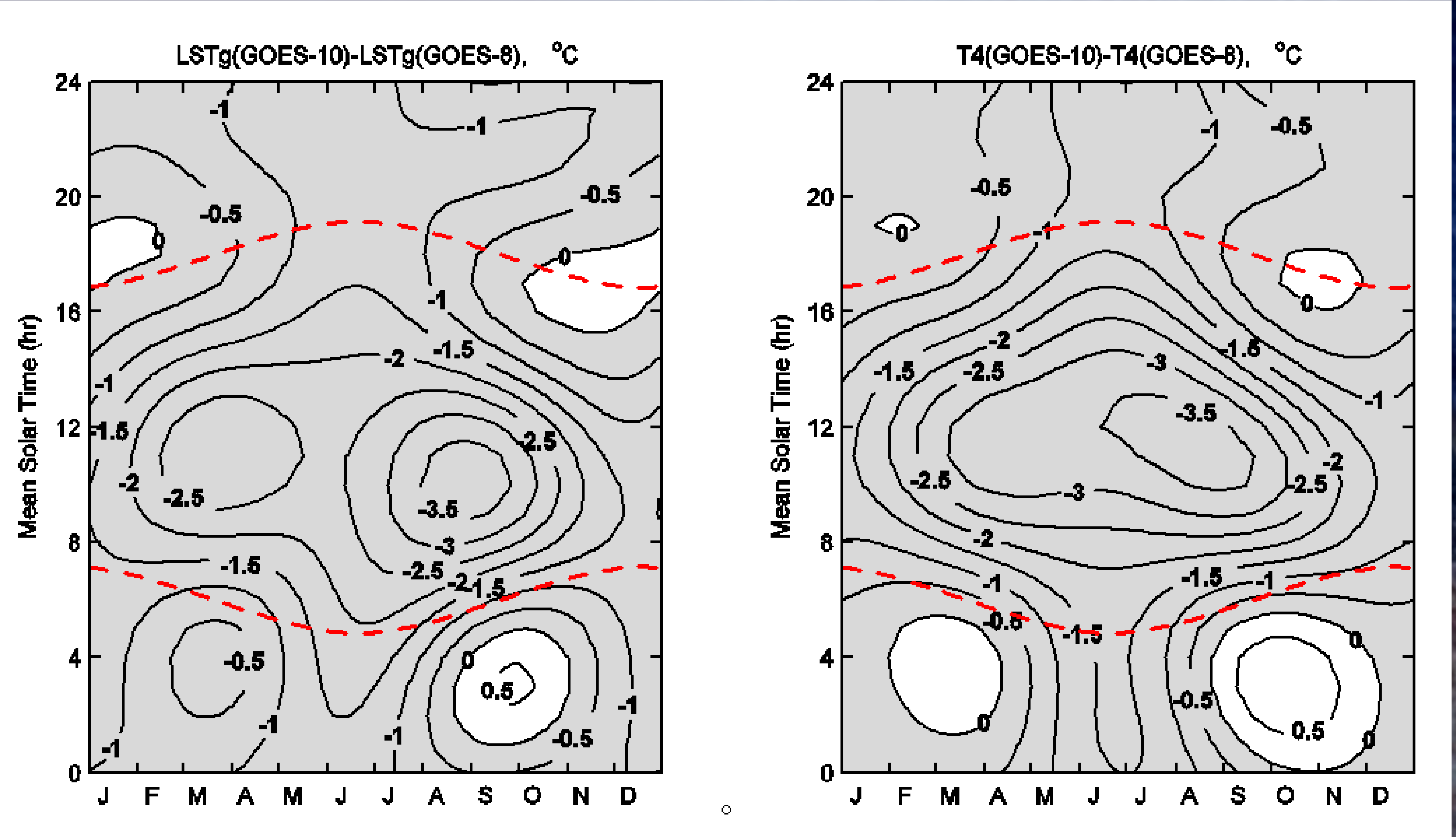
View zenith of GOES-8: $60.14^0$

View zenith of GOES-10: $46.81^0$



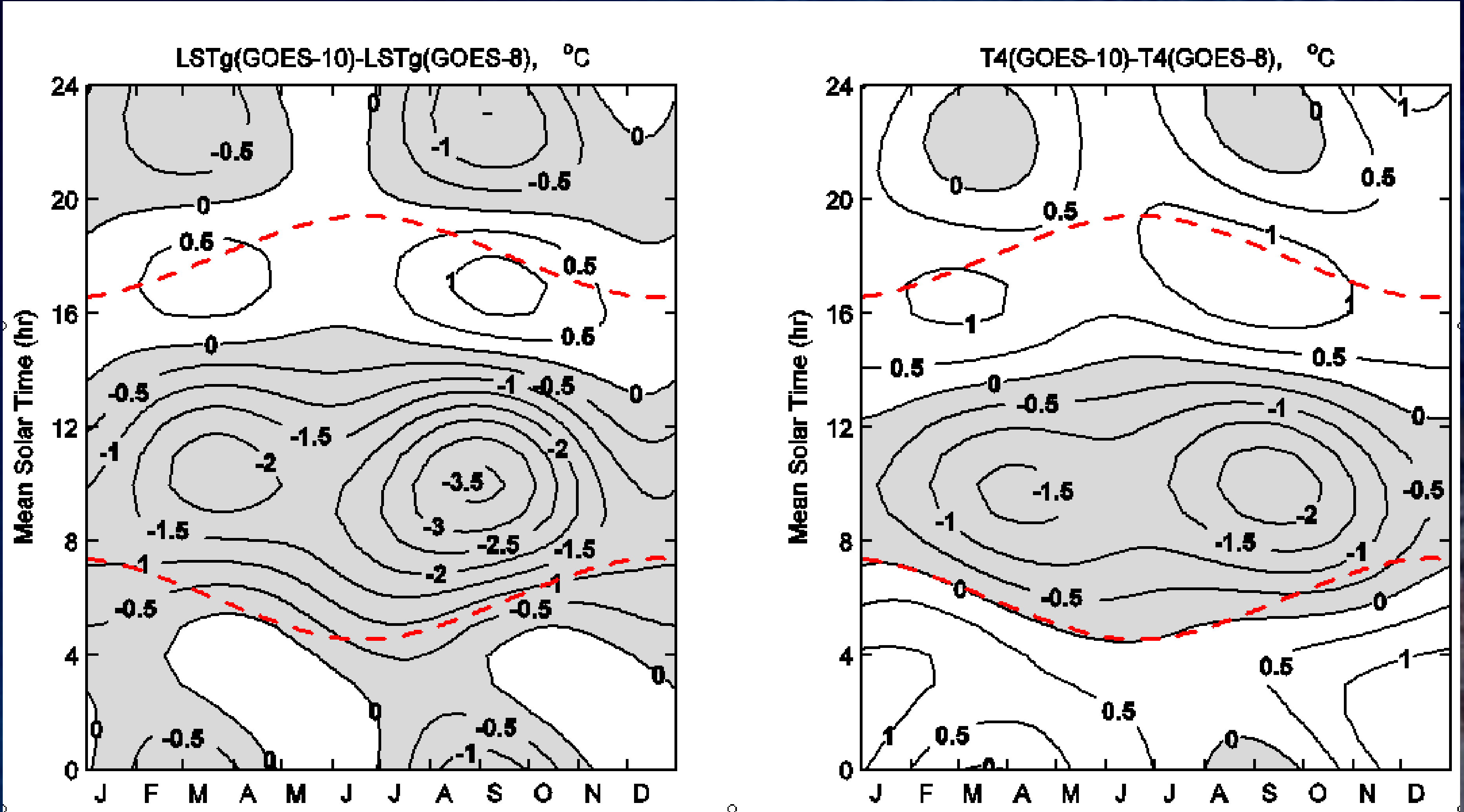
# LST Directional Effect in GOES-8 and -10 Imager (2)

Goodwin Creek, MS, observation pairs are about 510. View Zenith of GOES-8/-10: 42.68$^0$/61.89$^0$



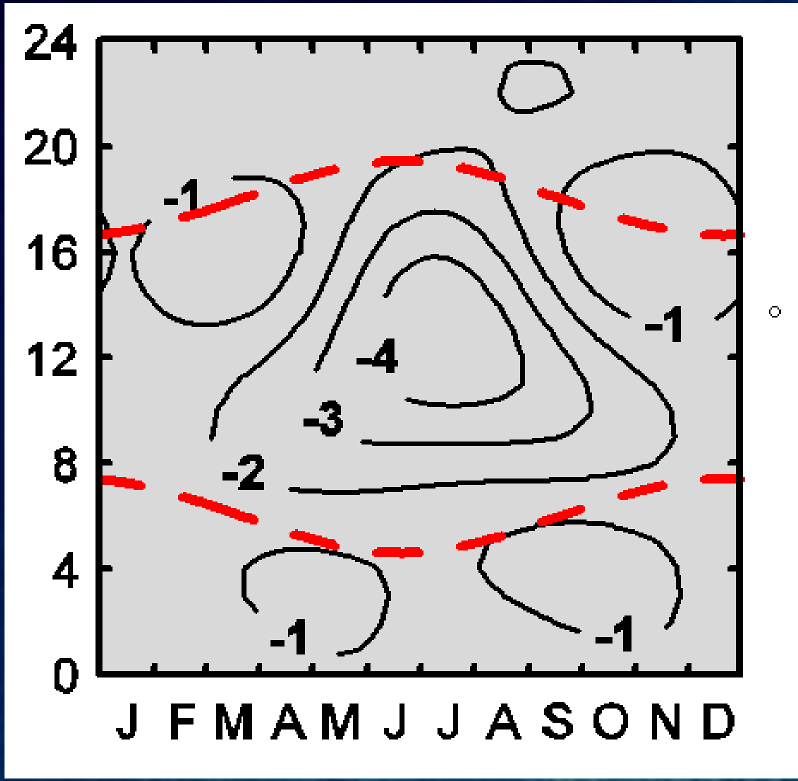
# LST Directional Effect in GOES-8 and -10 Imager (3)

**Boulder, CO, observation pairs are about 510.** View Zenith of GOES-8/-10: $42.68^0/61.89^0$



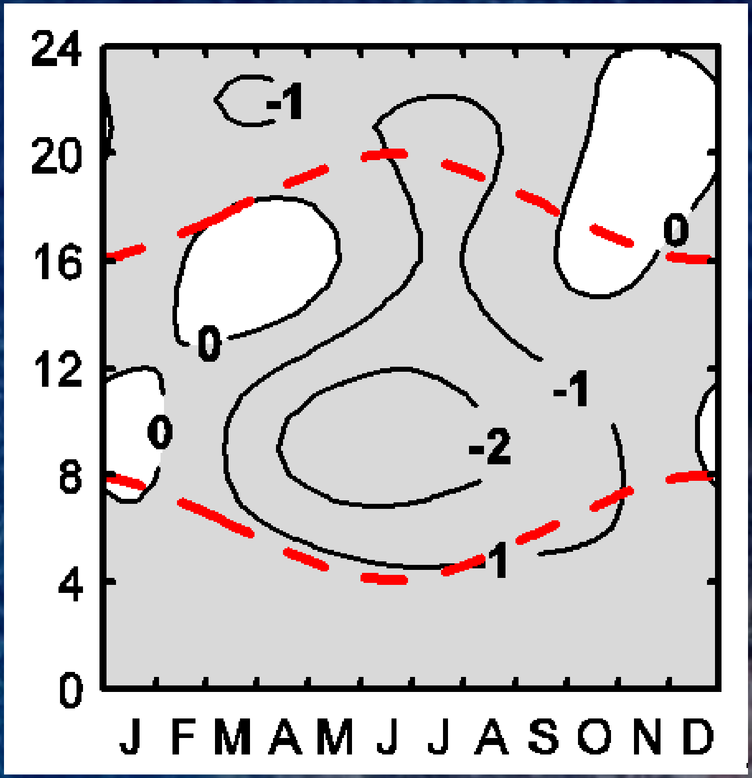
# LST Directional Effect in GOES-8 and -10 Imager (4)

**Bondville, IL. Data pairs: 710**




View Zenith of GOES-8: 48.12$^0$
View Zenith of GOES-10: 66.14$^0$

**Fort Peck, MT. Data pairs: 912**




View Zenith of GOES-8: 62.42$^0$
View Zenith of GOES-10: 62.36$^0$

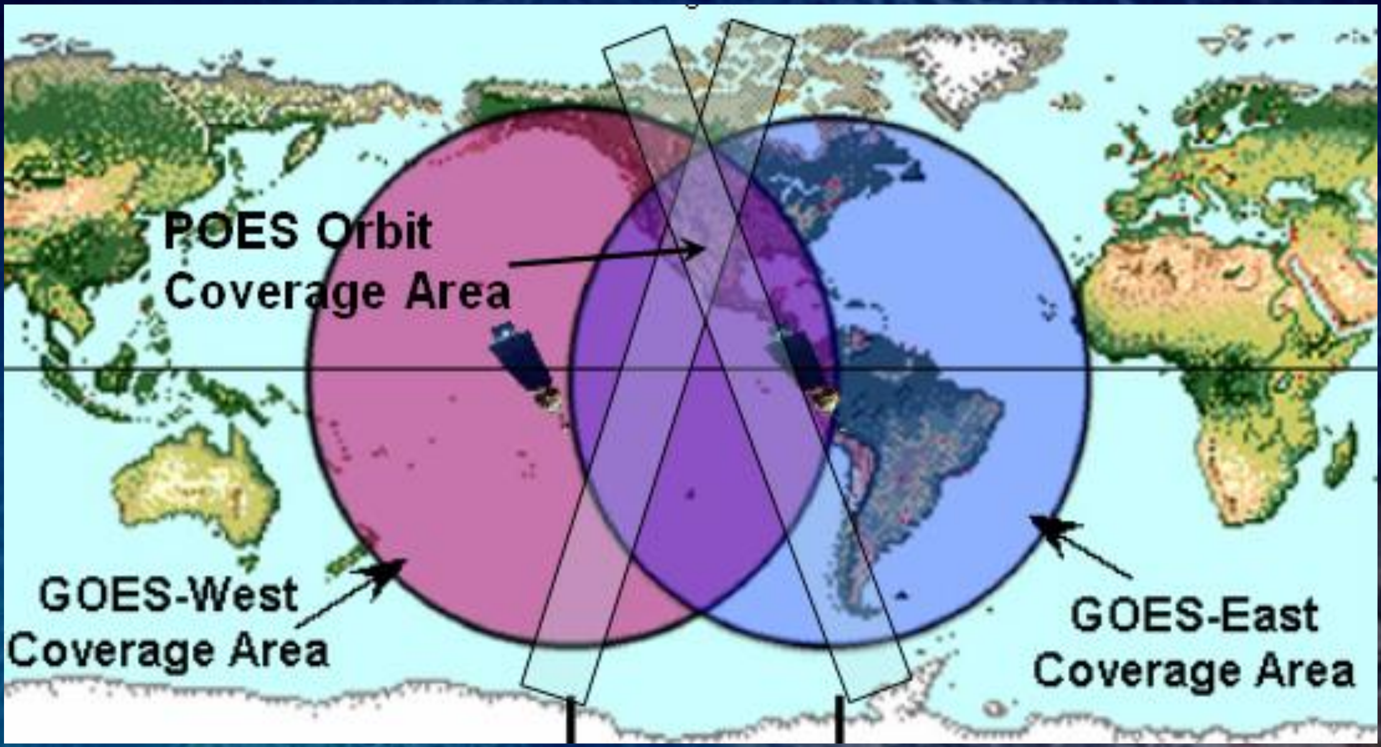
**Note the difference of the two sites**

# Summary

- Summary
  - » LST directional effect were observed from Polar-orbiting satellite data (NOAA/AVHRR) and Goestationary satellite data (GOES/Imager)
  - » LST difference due to the viewing angle difference changes diurnally; the effect during daytime is considerable bigger than that is during nighttime.
  - » The satellite LST uncertainty due to the directional effect is considerably larger comparing to the requirement, and cannot be ignored (particularly during the daytime).
  - » VIIRS/LST should provide correction/complimentary information on it after the launch (do work from now).

# Possible Solution?

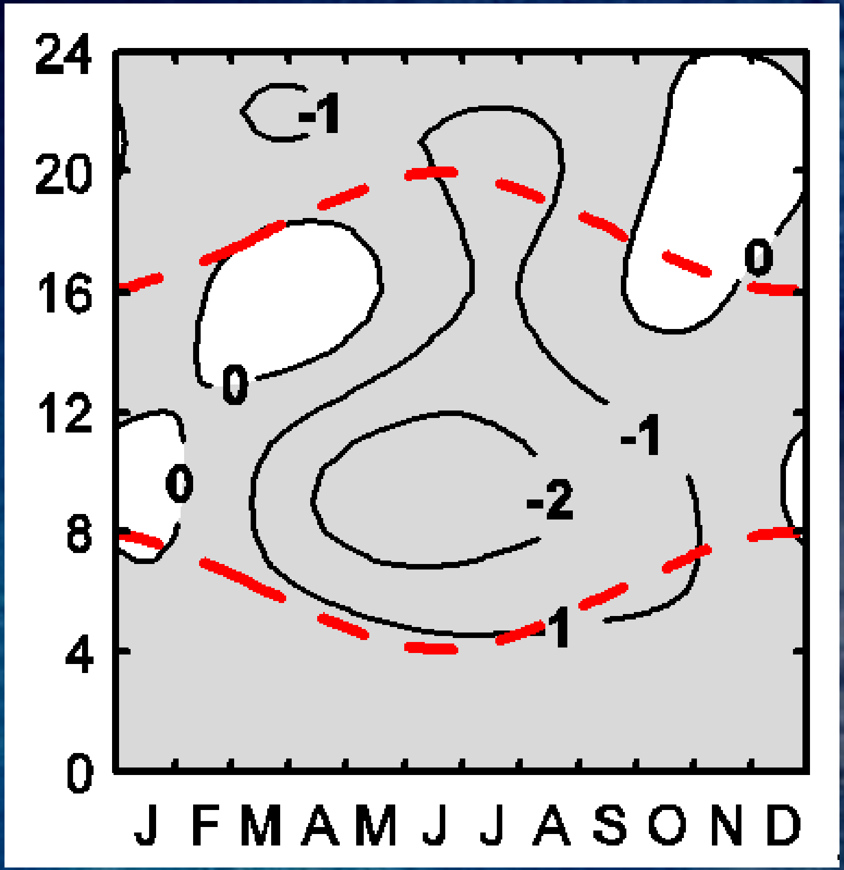
Different satellite observations over common areas can be calibrated each other for the data consistency.



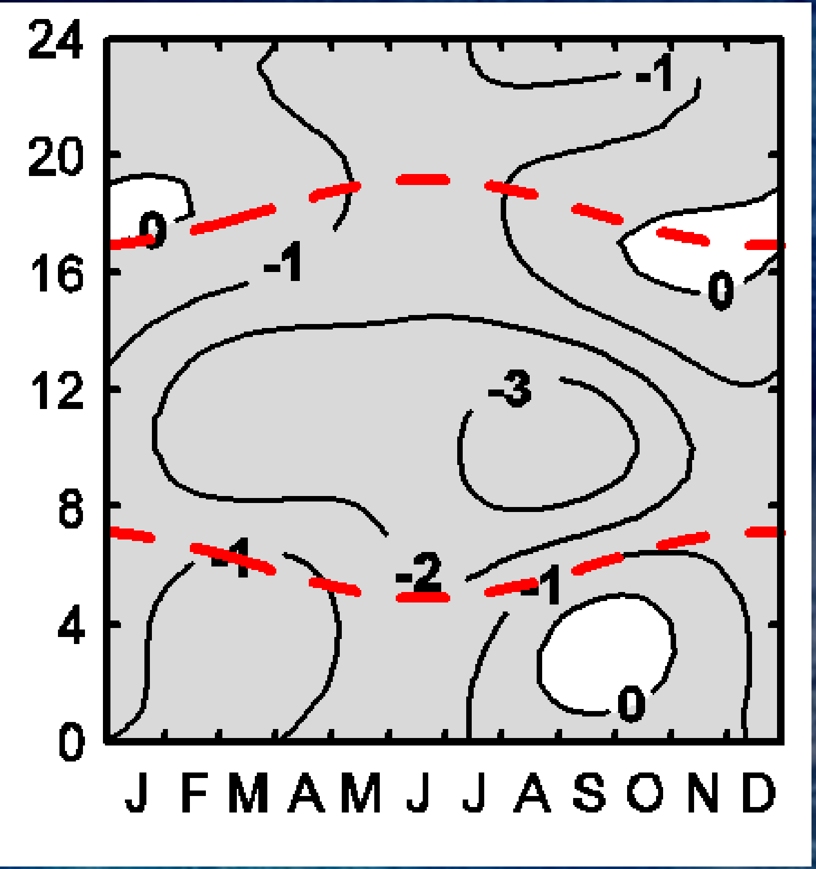

Sample of common area observed by GOES-E, GOES-W and POES satellites. LSTs derived from those satellite data will be used to develop an unified LST algorithm.

- Back-ups

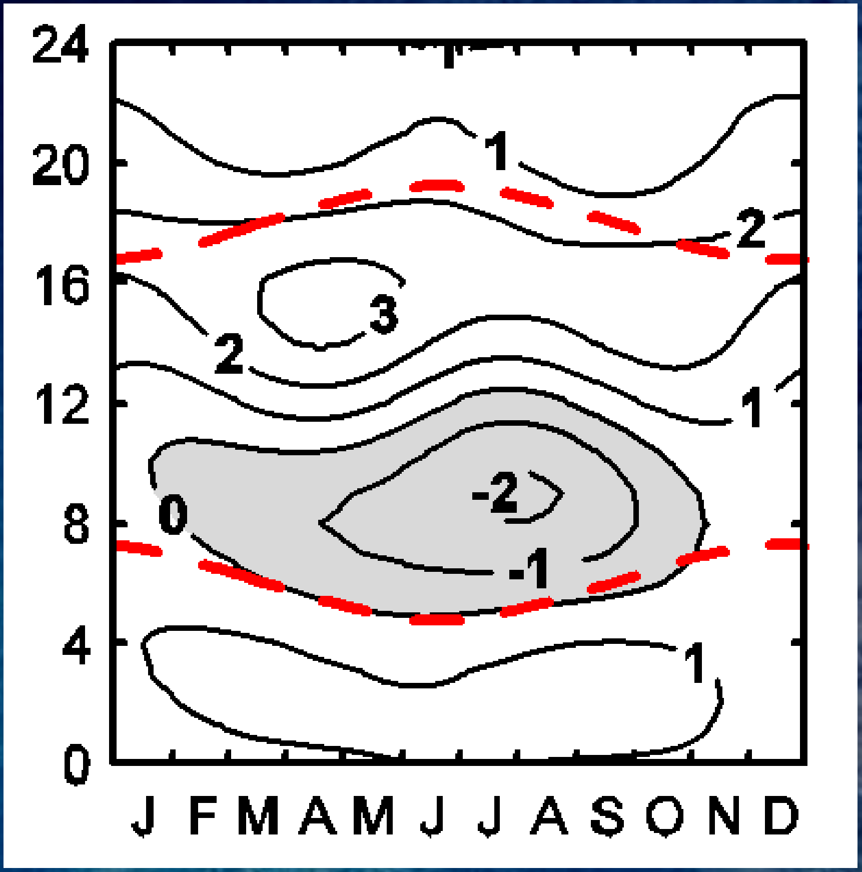
# Fort Peck



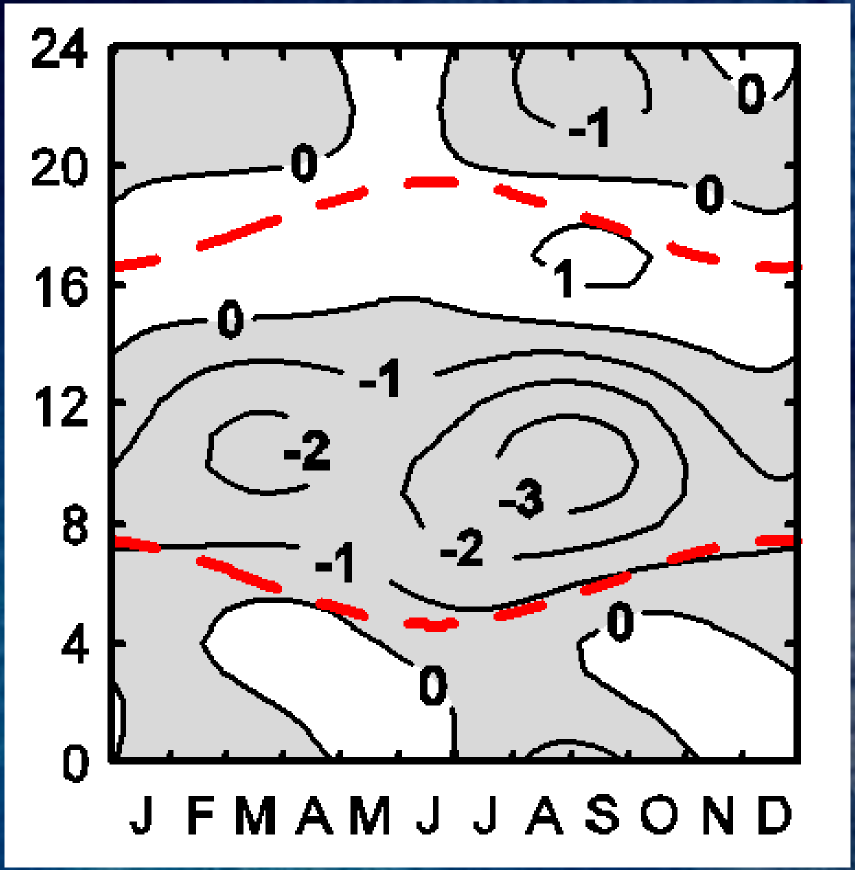
# Goodwin Creek



# Desert Rock



# Boulder



## *WE CAN TRY TO USE NIGHTTIME OBSERVATION TO EVALUATE SYSTEMATIC ERRORS IN LST*

**Mean differences $\Delta_{i,j}$ *between nighttime observed LST.***

| SURFRAD Network | Systematic Differences, $\Delta_{i,j}$, ºC | | |
|---|---|---|---|
| Station Name | *GOES -8 - SURFRAD* | *GOES -10 - SURFRAD* | *GOES -10 – GOES -8* |
| | $\Delta_{2,1}$ | $\Delta_{3,1}$ | $\Delta_{3,2}$ |
| Goodwin Creek, MS | 0.4 | -0.3 | -0.8 |
| Desert Rock, NV | -3.2 | -2.3 | 0.9 |
| Bondville, IL | -0.1 | -1.4 | -1.3 |
| Boulder, CO | -1.1 | -1.2 | -0.2 |
| Fort Peck, MT | -0.8 | -1.1 | -0.3 |
| AVERAGE | -1.0 | -1.3 | -0.3 |

**Let us consider that nighttime LST observation at five selected SURFRAD stations is unbiased. In such assumption all GOES-8 observed LST should be corrected by adding constant bias ~1.0 ºC, and all GOES-10 observed LST should be corrected by adding constant bias ~1.3 ºC. This table will be recomputed!**